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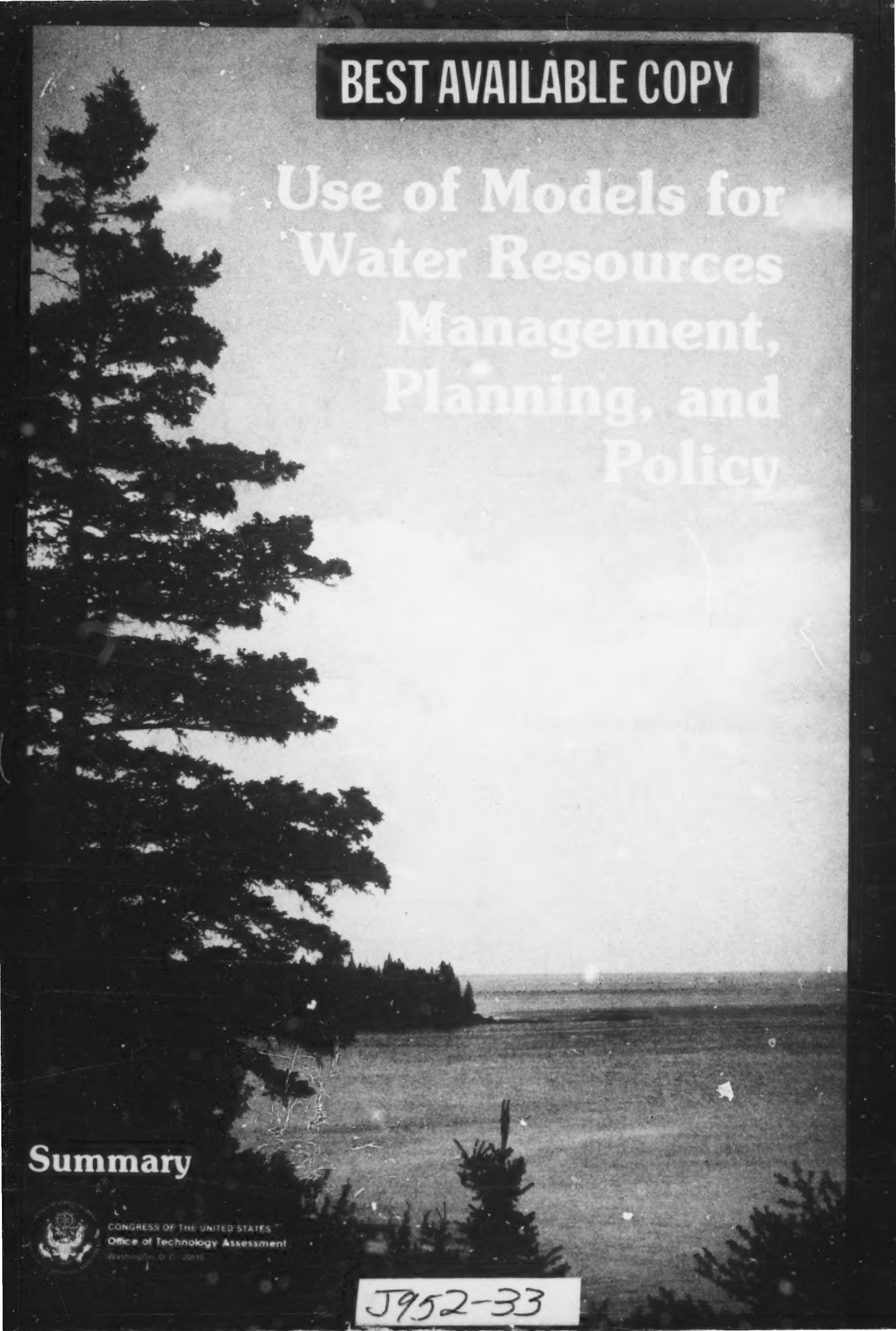
Use of Models for Water Resources Management, Planning, and Policy



Summary

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Foreword

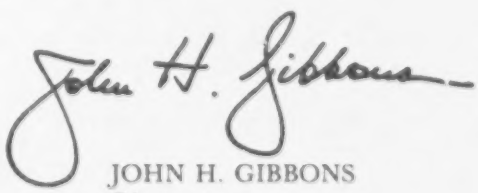
As the Nation grows, and excess water supplies diminish, it becomes increasingly important to manage existing supplies with the greatest possible efficiency. In recent years, successful management and planning of water resources has increasingly been based on the results of mathematical models. This part of water resource management, though not as apparent as dams and reservoirs or pipes and sewers, is a vital component in meeting the Nation's water resource needs. Sophisticated analysis, through the use of models, can improve our understanding of water resources and water resource activities, and help prevent wasting both water and money.

This assessment of water resource models is therefore not an assessment of mathematical equations or computers, but of the Nation's ability to use models to more efficiently and effectively analyze and solve our water resource problems. The assessment considers not only the usefulness of the technology—the models—but the ability of Federal and State water resource agencies to apply these analytic tools effectively.

The capabilities of water resource models vary greatly from issue to issue. In a number of areas, further research and development is needed, but in other areas, usable and reliable tools currently exist. However, as often occurs, these technologies have outstripped the capabilities of Federal, State, and local agencies to support and effectively use them. Today, model use is increasing the efficiency and lowering the cost of water resource management, but the potential for further improvement remains great.

This summary presents options for improving Federal, State, and local use of available technologies to analyze water resource problems. Opportunities are identified for congressional action to improve water resource management capabilities through selective model use—throughout the Federal Government, within individual Federal agencies, and among State and local governments.

About 40 water resources professionals from Federal and State agencies, universities, and the private sector contributed to this report. OTA was also aided by representatives from 27 Federal agencies and offices, and from all 50 States, who provided information in response to OTA surveys and inquiries regarding model use, as well as by Federal, university, and private sector participants in two series of workshops on modeling issues. OTA expresses sincere appreciation to all these individuals for helping bring an imposing amount of collective wisdom to this analysis.



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OTA appreciates the assistance of many additional people who contributed to this report:

- Participants at the two OTA water resource modeling workshops.
- Federal agency personnel who responded to the OTA Federal agency survey.
- State agency personnel who responded to the OTA State agency survey and directors of the State water resources research institutes who suggested appropriate respondents.
- The professional societies that reviewed technical materials, including the American Geophysical Union, the American Society of Civil Engineers, the American Water Resources Association, and the National Water Well Association.

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Use of Models for Water Resources Management, Planning, and Policy

SCOPE

This assessment is intended as a guide for Congress on the potential to develop and use mathematical models to more effectively and efficiently analyze the Nation's water resource problems. Policy options are presented for improving the use of these tools within both Federal and State water resource agencies.

The assessment reviews the current technical capabilities of models; the current and potential use of models by Federal and State agencies; and general impediments to effective model development, use, and dissemination. It draws on the results of surveys of water resource professionals in 27 Federal agencies and offices, from all 50 States, and from universities and the private sector.

Mathematical models are new technologies that are increasingly being used for water analysis. The Office of Technology Assessment (OTA) focused on mathematical modeling as a means of assessing the broader issue of our ability to analyze and plan courses of action to deal with current and long-range water problems. OTA did not investigate the more traditional forms of water resource analysis that are being replaced by mathematical models, or the less commonly used physical models.

The technical capabilities of models vary greatly among the water resource issues analyzed in this report; however, the assessment finds that models capable of analyzing many pressing water resource issues are currently available, and have significant potential for increasing the accuracy and effectiveness of information available to managers, decisionmakers, and scientists. Institutional constraints to model use, including lack of information about available models, lack of training in model use and interpretation, lack of communication between decisionmakers and modelers, and lack of general support services, are identified as major impediments to increased model use for water resource analysis.

The full report includes:

- **Chapter 1—Summary, Issues, and Options,** discusses the major findings of the report and includes five issues (with options) appropriate for congressional consideration.
- **Chapter 2—Introduction to Water Resource Models,** is a primer on models and their use in water resource management, planning, and policy.
- **Chapter 3—General Issues in Model Development, Use, and Dissemination,** discusses support services necessary for making effective use of models (e.g., training, user assistance, and model maintenance) as well as other general issues, including model evaluation and legal aspects of model use.
- **Chapter 4—Federal Use and Support of Water Resource Models,** analyzes current Federal modeling capabilities and discusses current approaches to Federal model management. A discussion of the purposes, strengths and weaknesses of 11 Federal institutions with responsibilities for model development, dissemination, or use is included.
- **Chapter 5—Use of Models by State Governments,** presents trends in current and potential State model use, discusses State-perceived constraints to model use, and describes State model use for 33 major water resource issues.
- **Chapter 6—Modeling and Water Resource Issues,** reviews the state of the art and appropriate roles for model use in management, planning, and policy activities. The chapter explains in nontechnical terms the capabilities and limitations of models for analyzing 32 major water resource issues.
- **Appendixes** document the results of the OTA workshops, surveys, and technical evaluations of currently available models.

INTRODUCTION

Between 1950 and 1975, the Federal Government spent over $45 billion to develop, maintain, and improve the Nation's water resources;* expenditures have spiralled to even higher levels over the past decade. Federal efforts range from constructing dams to increase the reliability of water supplies, generate hydroelectric power, improve flood control, and provide recreational opportunities; to studies for determining whether flood plain areas are sufficiently safe to permit building activities; to providing wastewater treatment for reducing health and environmental risks due to polluted rivers, streams, and lakes.

Decisions affecting water resources are made by the Federal, State, and local governments, and by the private sector. These decisions include designing day-to-day management procedures for operating facilities most efficiently, as well as planning and implementing long-range policies for water resources management and construction. Decisions of the latter kind involve large sums of money, and may affect the availability and quality of water for many decades to come.

*The $45 billion estimate includes expenditures by the Army Corps of Engineers, the Bureau of Reclamation, the Soil Conservation Service, the Tennessee Valley Authority, and the Environmental Protection Agency's Construction Grants Program outlays.

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Mathematical models are among the most sophisticated tools available for analyzing water resource issues. They can use the capabilities of today's digital computers to perform and integrate millions of calculations within seconds, in order to understand and project the consequences of alternative management, planning, or policy-level activities. Models only assist in decisionmaking—they provide information that people must interpret in light of existing laws, political and institutional structures, and informed professional and scientific judgment. Nonetheless, models can significantly improve the informational background on which decisions are based, and substantially reduce the cost of managing water resources. Although the Federal Government spends approximately $50 million on water-related mathematical models annually, such tools are instrumental in planning billions of dollars of annual water resource investments, and managing hundreds of billions of dollars of existing facilities.

The role of models in managing water resources has grown dramatically over the past decade—a period in which water resource management itself has become increasingly important. High rates of economic and population growth in water-short areas of the country, decreased availability of water from major ground water aquifers, and increased public concern for the quality of its drinking water, lakes, and rivers have made it even more necessary to manage water resources carefully. In addition, the issue of who is to manage water resources has gained prominence in the political arena, as ways are sought to increase States' responsibilities for assuring adequate and safe water supplies.

The magnitude of the national investment in water resources calls for systematic use of the best analytic tools available to manage this investment. Over the past 20 years, models and sophisticated data processing systems have been advanced as promising great improvements in water resources management, planning, and policy. Yet many consider that these tools have not yet lived up to earlier expectations. OTA was requested to study the use of models in freshwater resources analysis in order to determine their current capabilities, identify appropriate roles for their use, and suggest options for improving modeling efforts and model use.

FINDINGS

Mathematical models have significantly expanded the Nation's ability to understand and manage its water resources. They are currently used to investigate virtually every type of water resource problem; for small- and large-scale studies and projects; and at all levels of decisionmaking. In some cases, **models have increased the accuracy of estimates of future events** to a level far beyond "best judgment" decisions. In other areas, **they have made possible analyses that could not be performed empirically or without computer assistance.** Further, models have made it feasible to quantitatively compare the likely effects of alternative resource decisions.

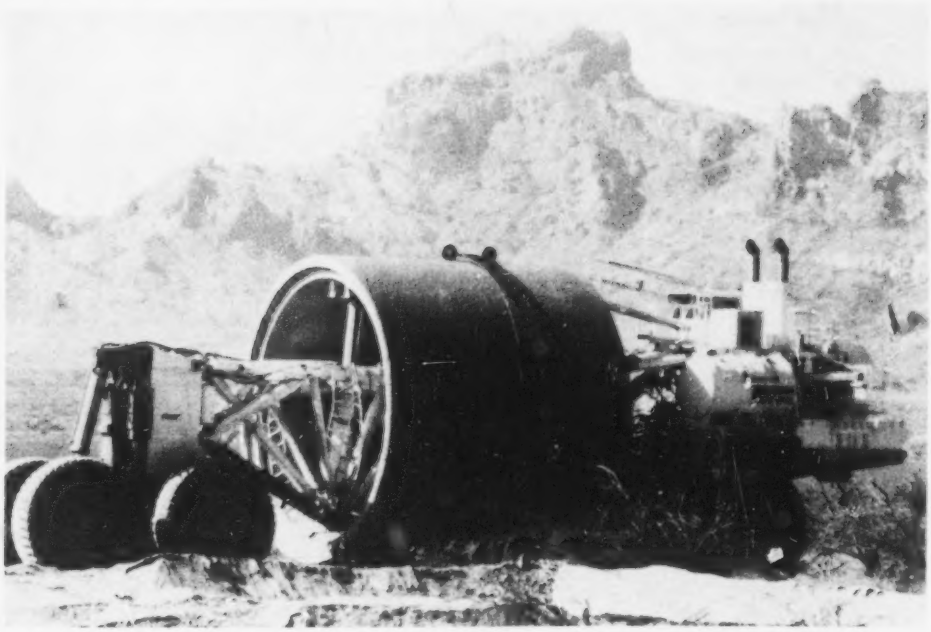

Photo credits: © Ted Spiegel, 1982

Pipelines to provide new supplies of water for the State of Arizona (top) and the New York City water tunnel (bottom) demonstrate the magnitude of the Nation's water resource needs. Reliable forecasts of an area's water requirements are critical for designing efficient and adequate water transport and distribution systems. Models can be used to estimate future demands for water, and to assist in water system design

Models are often the best available alternative for analyzing complex resource problems. While many of the economic and social factors in water resource decisions cannot be fully enumerated, models can be used to integrate the available data, and provide estimates of future effects and activities. Such estimates are highly useful in evaluating the consequences of different resource policy options, and are often less expensive than conducting comprehensive surveys and using other traditional approaches.

Models have the potential to provide even greater benefits for water resource decisionmaking in the future. As models are refined and receive wider acceptance, **they will be able to increase the efficiency of water resource management and encourage cost-effective decisionmaking.** Such models can do much to increase the rationality of regulations and the standard-setting process, and can generally provide a sound scientific basis for water policy. The following examples illustrate the potential benefits of future expansion in model use:

- Between 1950 and 1975, the Tennessee Valley Authority (TVA) spent over $2 billion for water resources development and management. Improving rainfall forecasting and reservoir scheduling can make a very significant contribution to the benefits that accrue from these water development projects. Recent studies on six TVA reservoirs found the potential for a 20-percent improvement in operations and annual savings of $4 million through the implementation of a system of reservoir scheduling models.
- NWS estimated that the installation of a $200,000 modeling system to forecast floods on the Connecticut River basin would provide a reduction in flood damages exceeding $1.5 million per year.
- Models assist farmers in scheduling irrigations to optimize water conservation while maintaining crop productivity. In Nebraska, improved irrigation scheduling has resulted in 25- to 35-percent savings in water pumped and energy costs per year.
- Cornell University investigators developed a systems optimization method to design a sewer network for the Long Island Regional Planning Board. The resulting analysis indicated that a sewer network that would meet community needs could be built and operated for $40 million less than could a design developed by a firm using conventional analytical methods.

Water resource models vary greatly in their capabilities and limitations and must be carefully selected and used by knowledgeable professionals. In some instances, decisionmakers need only "ballpark" accuracy to make decisions, but in other instances model accuracy may be extremely important. A decisionmaker may require a different model in each case, even though similar kinds of problems are being analyzed.

Since modeling is a rapidly advancing and highly specialized field, **it is extremely difficult for decisionmakers and managers to stay abreast of new developments,** or even to fully understand the

capabilities and limitations of the tools they currently employ. Under such circumstances, a certain amount of model misuse and mistrust is virtually inevitable. Managers may also perceive models as an undesirable constraint to their authority and decisionmaking capabilities. However, models are most effectively used as an *aid* to decisionmaking, rather than as a *substitute* for the decisionmaker's judgment.

Models are not explicitly required in any Federal water resource legislation, but they are often the method of choice to meet the requirements of legislation. Many current laws regarding water resources require analytical work normally done in whole or in part by models. Major Federal legislation associated with model use at Federal, State, or local levels includes:

- Clean Water Act (Public Law 95-217)—sections 107, 201, 208, 209, 301, 302, 303, 307, 311, 314, 316, 404, and 405;
- Safe Drinking Water Act (Public Law 93-523)—sections 1412, 1421, 1422, 1424, 1443, and 1444;
- Toxic Substances Control Act (Public Law 94-469)—sections 4, 5, and 6;
- Resource Conservation and Recovery Act (Public Law 94-580)—sections 1008 and 8006;
- Endangered Species Act (Public Law 93-205)—section 7;
- Surface Mining Control and Reclamation Act (Public Law 95-87)—sections 506, 510, and 515;
- Soil and Water Resource Conservation Act (Public Law 95-192)—sections 5 and 6;
- Water Resources Planning Act (Public Law 89-80)—section 102;
- Coastal Zone Management Act (Public Law 94-370)—section 305;
- Executive Order No. 11988 (Floodplain Management);
- Flood Control Act of 1936 and Amendments—sections 1, 2, and 3;
- National Flood Insurance Act of 1968—section 73;
- Water Research and Development Act (Public Law 95-467)—section 1360;
- Federal Reclamation Act of 1902 and Amendments—43 U.S.C. 421 and 422;
- National Environmental Policy Act (Public Law 91-190)—sections 102 and 103; and
- Atomic Energy Act of 1954—10 CFR 20, 50, 61.

In translating legislative requirements into management practices, agencies often recommend procedures that depend on the use of models. The Clean Water Act, for instance, requires States to determine the "total maximum daily loads" for those sources of pollutants that cannot meet water quality standards through effluent limitations regulations. This requires States to predict the water quality resulting from a number of point-source loadings—a responsibility that implicitly requires the use of "wasteload allocation" models.

Developing and using models is a complex undertaking, requiring personnel with highly developed technical capabilities, as well as

adequate budgetary support for computer facilities, collecting and processing data, and numerous additional support services. Such capabilities presently reside primarily within the Federal Government, or are secured from the private sector with Federal funding. For fiscal year 1979, direct and indirect **Federal expenditures in support of model development, dissemination, and use for water resources are estimated at $40 million to $50 million annually.** The Army Corps of Engineers, the U.S. Geological Survey (USGS), and the Environmental Protection Agency (EPA) are the principal agencies involved in water resource modeling activities, and together they account for approximately 70 percent of the funds spent in support of water modeling at the Federal level. **These expenditures represent an ongoing investment in information that supports and improves expenditures of billions of dollars annually for water resource development and management.**

Federal training and assistance is also important in assuring the continuing availability of hydrologists, engineers, and modelers with expertise in water resource issues. The demand for well-trained water resource professionals at Federal, State, and local government levels, as well as in the private sector, far exceeds the number of individuals who graduate annually with relevant skills from American colleges and universities. In addition, a number of Federal agencies offer important training opportunities in water resources analysis and modeling for Federal and non-Federal employees alike. While such training is often critical for keeping professional employees abreast of developments in these fields, current levels of instruction are clearly insufficient to meet the growing needs of Federal, State, and local personnel.

Virtually all Federal modeling activities are currently managed on an agency-by-agency basis. Little coordination of model development, dissemination, or use occurs among Federal agencies, and effective joint modeling efforts are rare. Agencies generally have little information about models available through or being developed by other agencies; consequently, agencies tend to develop new models before taking advantage of previous or ongoing modeling efforts of other agencies. While independent agency-level development may produce tools that are more responsive to specific agency needs, the lack of cooperative development has often resulted in agencies being unable to muster the resources to adequately develop and support needed models. Testing models is a difficult, expensive process and very often a major barrier in the way of model use.

Most Federal agencies have no overall strategy for the development and use of models; consequently many legislative requirements and decisionmaker needs for information are not being met. Due to the newness and technical complexity of the modeling field, **levels of communication between decisionmakers and**

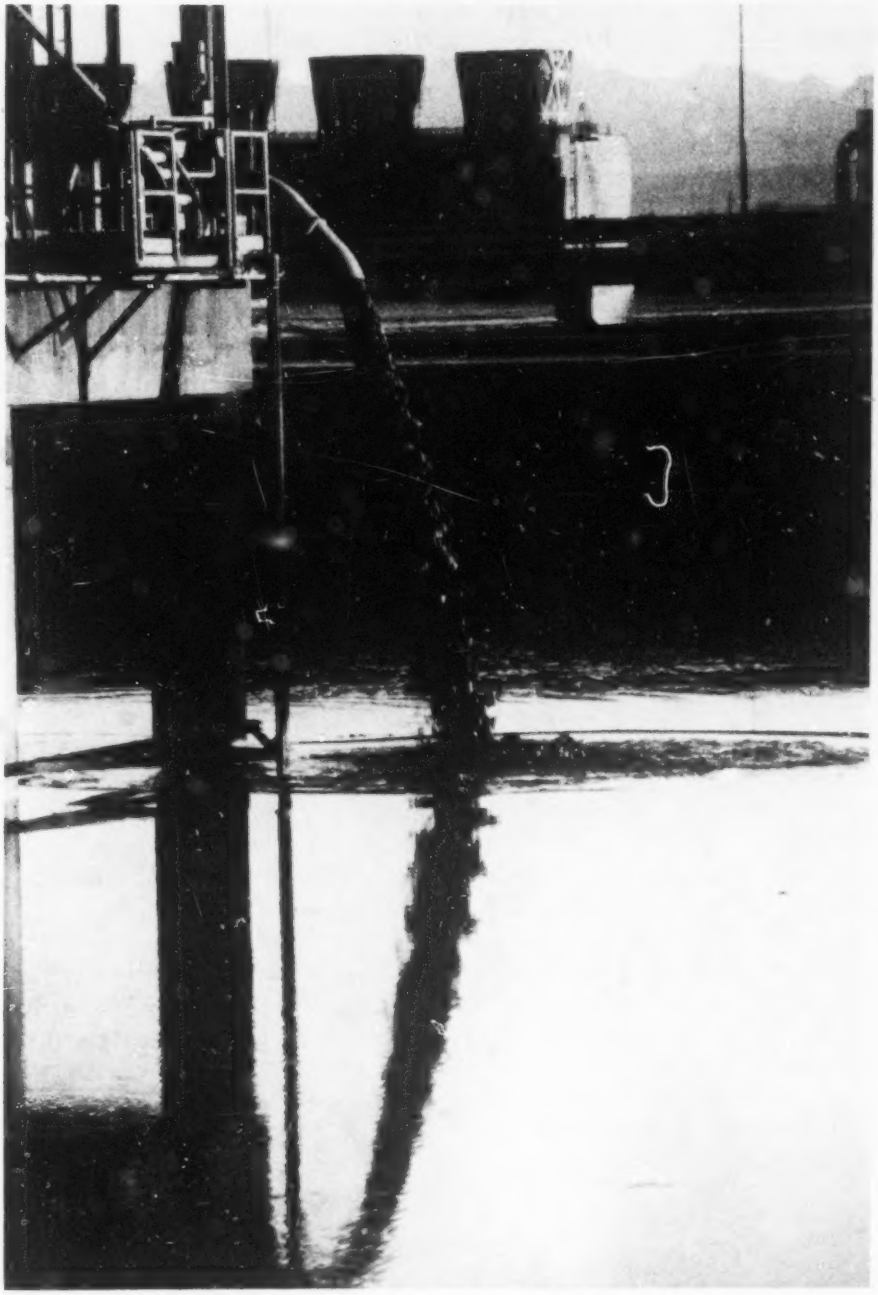

Photo credit: © Ted Spiegel, 1982

Models are important tools for determining whether individual point-sources of water pollution will prevent rivers, lakes, and streams from meeting Federal water quality standards. Using models, planners can determine what levels of discharge would be acceptable *before treatment facilities are installed;* such information is extremely valuable for designing effective treatment strategies

modelers are low, and little coordination of model development, dissemination, or use occurs *within* individual Federal agencies.

Successful modeling requires adequate resources for support services, such as user assistance, as well as for development. Presently, model development has outstripped corresponding support for models. In the past, model developers have put a premium on developing models, while support for models—documentation, validation, dissemination, user assistance, and maintenance—has been neglected. Often, resources are focused on development, but are unavailable for support activities. The neglect of model support has led to a multiplicity of models, most of which are underutilized. Many of these models cannot be used by personnel other than the developer, due to lack of documentation, access to the model, and user assistance.

Federal agencies that have had considerable success with modeling have devoted substantial attention to the problem-solving needs of potential users and decisionmakers, and to providing adequate support services. These programs generally include a central responsibility for disseminating software and documentation, providing training and technical assistance, and updating and maintaining models.

State governments frequently use water resource models, although many wish to use them more extensively than is currently possible. OTA's survey of State water resources professionals indicates that ***potential* levels of model use at the State level are at least twice as high as *current* use levels.** Technical capabilities at the State level tend to be limited—staffs are small, and prevailing salary scales prevent many States from hiring and/or retaining adequate numbers of personnel with modeling skills. Consequently, **most States depend primarily on the Federal Government to provide them with suitable models, technical expertise, and training in model use.** Those Federal agencies that have had considerable success in assisting States have made substantial commitments to providing support services—USGS runs a cooperative program that currently assists over 600 State and local agencies in developing and applying models, while the Corps of Engineers' Hydrologic Engineering Center (HEC) widely provides services to State and local governments, and assists them in using HEC-built models.

Lack of information is a major barrier to State and local use of models—personnel are often unaware that models for a given type of analysis already exist. Additionally, many federally developed models are inappropriate for use at the State level. The specific needs of States are infrequently considered in Federal model development. Many States reported that their analytic and modeling capabilities must be expanded if States are to assume a larger role in future water resource decisionmaking.

ISSUES

The issues discussed in this section focus on the potential to improve the Federal role in developing, using, and disseminating water resource models. Opportunities for increasing the efficiency and effectiveness of current model-related efforts and programs are noted, although the general nature of the options set forth prohibit development of specific cost estimates or estimates of the potential savings associated with a given option. Each option presented for congressional consideration is designed to increase the productivity of the billions of dollars invested annually in water resources and water resource management. Issues 1 and 3, "Improving Federal Problem-Solving Capabilities," and "Establishing Appropriate Modeling Strategies Within Individual Federal Agencies," are directed toward making more effective use of the approximately $50 million per year spent by the Federal Government on water resource modeling; issues 2, 4, and 5, "Meeting the Needs of the States," "Providing Potential Users With Information About Existing Models," and "Federal Support for Model-Related Training," focus on improving modeling capabilities through the provision of augmented model-related services.

Issue 1: Improving Federal Problem-Solving Capabilities

Many of the analytic responsibilities mandated by Federal and State water resources legislation cannot adequately be carried out without models. However, **the analytic tools needed to fulfill many legislative requirements and decisionmaker information needs are currently unavailable. The majority of Federal agencies have no overall strategy for developing, using, disseminating, and maintaining these tools.** Models tend to be built on an ad hoc basis, in response to immediate problems, rather than as a result of integrated planning. In the absence of any comprehensive model development and support strategy, Federal agencies are often unresponsive to State and Federal problem-solving needs, or to congressional directives expressed in water resources legislation.

Most water resource problems, and the Federal legislation that deals with them, affect a number of Federal agencies. However, each agency is individually responsible for developing and funding the analytic tools it requires. While many models have widespread potential use among a variety of Federal institutions, it is often impossible for any one agency to commit the personnel and financial resources necessary to bring them to completion. **Unless clear direction and priority-setting mechanisms are provided by Congress and the Executive Office of the President, the best analytic tools will not be available throughout the Federal Government, and many needed models will not be built or supported.**

At present, minimal Federal oversight exists for the funding of applied research and development (R&D) activities. The mechanisms that currently exist for coordinating water resources analysis focus almost entirely on research needs. Neither the information required for solving policy problems nor the analytic techniques needed to aid in decisionmaking are directly addressed in the current process for coordinating the Federal R&D agenda in water resources. Under the Water Research and Development Act of 1978, the Secretary of the Interior is presently directed to develop a 5-year water resources research program, drawing on the expertise and advice of appropriate Federal agencies, the State water resources research institutes, and other appropriate entities. The program is to indicate goals, objectives, priorities, and funding recommendations to the President and Congress for water resources R&D. That document is intended to serve as the basis for funding allocations in the budget processes of Congress and the Executive Office of the President.

While the 1978 act recognizes the need to strengthen, "The capability for assessment, planning, and policy-formulation . . . at the Federal and State level," it provides no specific direction to determine what mix of research and problem-solving capabilities can best meet Federal needs. Moreover, **by concentrating primarily on research needs, it misdirects mission agency priorities toward research per se rather than toward coordinated development and utilization of scientific knowledge and related analytic capabilities.** The research focus of the current act also reinforces tendencies within individual agencies to fund projects that reflect the agency's mission, rather than priority problems identified by Congress and the Executive Office of the President.

Options available to Congress include:

OPTION 1-A:

Congress could amend the Water Research and Development Act of 1978 to specify the development of a multiyear plan emphasizing a mix of R&D needs, usable analytic tools, and support services for ensuring that these tools are available to water managers.

Under the act, Congress has directed the Secretary of the Interior to develop a 5-year water resources research program. This mechanism for coordinating Federal efforts to help solve water resource problems might be more effective if a broader range of problem-solving needs were considered.

Mathematical models are an important component of the water resource analysis needs of Federal agencies. However, as with other forms of R&D, creating these tools is only the first step in establishing needed analytic capabilities. Over a dozen reports defining Federal water resources research needs have been prepared over the last 20 years. The latest of these, the National Research Council review of the draft Five-Year Plan specified by the act, lists major water resource problems, and further states that:

> For many of the foregoing problems the basic and applied research has already been accomplished in substantial part, if not entirely. What is often lacking, however, is adequate technology transfer . . . Solution of many other problems requires research and development to advance the state of knowledge.

As with previous plans, the latest Five-Year Plan proposal has not been as effective as it might have been, due to its emphasis on a research agenda. While models have been acknowledged as important *research* tools, little attention has been paid to developing the analytic tools and support capability needed to meet Federal and non-Federal water resource problem-solving responsibilities.

Congress could expand the scope of the Water Research and Development Act to specifically address a broader range of analytic and problem-solving needs for water resources decisionmaking, and provide a mechanism (such as an interagency coordinating committee) to carry out the intent of the act.

OPTION 1-B:

Congress could establish an interagency unit whose responsibilities include developing a multiyear plan for water resource analytical needs and coordinating the implementation of the plan.

Interagency representation may be necessary for successful coordination. This unit might be housed either within the Office of Science and Technology Policy or in an interagency water resources policy organization similar to the Water Resources Council or its potential successor. The unit might be directed to work closely with the Office of Management and Budget for budgetary review.

OPTION 1-C:

When addressing priority problems through legislation, Congress could establish specific mechanisms to provide adequate Federal water resource analytic capabilities to meet the intent of the legislation.

Congress could explicitly direct Federal agencies to provide institutional support for the analytic capabilities needed to implement legislative goals. A number of approaches could be used for providing these capabilities, including centers of excellence at universities, operating units within existing Government organizations, and agency and interagency demonstration programs for creating support units. One example of such support units is the Fish and Wildlife Service Instream Flow Group.

Issue 2: Meeting the Needs of the States

Most of the Nation's major water resource legislation is based on the concept of a strong State-Federal partnership for managing and planning the use and protection of the Nation's water. **If States are to fulfill their responsibilities, and take on an increasing share of**

water resource management delegations in the future, it is in the Nation's best interest to ensure that the States have access to, and are capable of using, the best available analytic tools.

Many States depend heavily on Federal agencies for assistance in modeling, and rely primarily on models that: 1) are widely available, 2) have a long history of use, and 3) are well supported by Federal agencies. Most States lack the financial resources and the technical expertise required to develop models independently. States frequently share common responsibilities or problems, and can take advantage of federally developed models designed for application to a wide variety of natural, social, and economic situations. Even for situations where differences among States require substantially different models, agencies of the Federal Government are important centers of expertise to which States turn for modeling assistance.

However, many of the models that Federal agencies routinely use are inappropriate to assist the States in fulfilling their water resources responsibilities. Even when agencies develop models that relate to State concerns, they often have no mandate to assist the States in analyzing their water resource problems. Consequently, many States find that such models are too complex to use, require more input data than States can afford to collect, or fail to meet specific State analytical needs.

Although a few agencies, such as EPA, solicit general input from the States through advisory panels or other means, **State needs are largely neglected in Federal agency modeling processes. If State agencies are to utilize Federal models to a greater extent, practical mechanisms must be devised for providing State input into the model development processes within individual Federal agencies.**

In addition, for the Federal Government to be effective in assisting States to analyze water resource issues, it must first develop reliable means of obtaining information about State needs. Mechanisms for assuring State input into Federal R&D processes, as specified under the Water Research and Development Act of 1978, are inadequate. The current act directs the 54 State (and territorial) water resources research institutes to develop 5-year research program reports in close consultation with appropriate State agencies, and to submit these to the Secretary of the Interior for use in developing a 5-year coordinated Federal water resources research program. Recent cutbacks in Federal support available to the institutes leaves many of them in a relatively weak position to voice State agency needs to the Federal Government.

Two additional pressing needs identified in the OTA survey of State water resource agencies are discussed in detail under issues 4 and 5: 1) better access to information about existing models; and 2) increased training opportunities in model use for State personnel.

Options available to Congress include:

OPTION 2-A:

Congress could direct the States to designate a lead State agency to assist the Secretary of the Interior, or other designee, in developing a multiyear plan for water resource analysis needs.

The Water Research and Development Act directs the State water resources research institutes, in consultation with State agencies, to provide input to the Five-Year Plan mandated by the act. If the Federal Government is to assist States in meeting water-related responsibilities, it must take into account a wide range of State water resource agency information and analytic needs. Congress could amend the act to allow the States to designate a lead State agency or a water resources research institute to participate in planning a broader multiyear Federal agenda.

OPTION 2-B:

Congress could strengthen the States' own capabilities to undertake sophisticated water resource analysis.

As the States' water resource management responsibilities have increased, so have the States' requirements for sophisticated water resource analysis. Improving the States' own analytic capabilities, either through federally sponsored training or by funding the States to develop and use their own analytic tools, could allow States to be less dependent on Federal agencies for analysis.

For example, the Clean Water Act (Public Law 95-217) directs the Administrator of EPA to make grants to planning agencies to develop a comprehensive water quality control plan for a river basin. Congress might consider similar programs for water resource development programs. If the States are to assume a greater role in the priority-setting process, Congress might consider including formula funding to strengthen States' analytic capabilities.

OPTION 2-C:

Congress could direct Federal water resource agencies to respond to the analytical needs of the States whenever States are to implement Federal programs.

For example, under the Safe Drinking Water Act, the States have primary enforcement responsibility for public water systems. The act specifically directs the Administrator of EPA to conduct research and demonstrations of "improved methods (i) to identify and measure the existence of contaminants in drinking water (including methods which may be used by State and local health and water officials), and (ii) to identify the source of such contaminants." One activity undertaken by EPA—funding the Holcomb Ground Water Model Clearinghouse—helps the States obtain ground water quality models used to identify the transport and fate of pollutants.

Congress could direct Federal agencies to establish similar mechanisms to assist the States whenever Federal programs are to be imple-

mented by the States, and ensure, through its oversight responsibility, that these programs are adequate.

Issue 3: Establishing Appropriate Modeling Strategies Within Individual Federal Agencies

Many of the major Federal water resource agencies lack an integrated plan for developing and supporting models. These agencies generally develop models in response to an immediate need to solve particular problems. Few attempts have been made to integrate related modeling efforts within each agency. Moreover, many models are produced without serious attention to decisionmakers' needs or significant managerial input. Models may not have been tested to determine their ranges of error and applicability to different conditions, and model assumptions and results may not be explained well enough to allow decisionmakers to interpret them properly. Consequently, some agencies may have a multiplicity of models, only a few of which are actually usable.

A few Federal agencies or offices, however, have established comprehensive strategies for developing and supporting models. These strategies generally take two different forms: 1) developing the capacity to analyze priority water resource problems encountered by many users, through a limited number of carefully selected models; or 2) developing a general capability for analyzing individual problems on a one-time or limited basis. Each involves different mixes of model development and support activities.

Developing selective modeling capabilities can be an effective strategy when frequently occurring priority problems appear to be solvable with some kind of standard technique. Models for dealing with these problems are generally developed in anticipation of repeated application by a variety of users. Their design must give close attention to user needs and capabilities. Models must be thoroughly explained, or *documented,* tested for use over a wide variety of conditions, easily accessible, and usable on many different computer facilities without major modifications.

To assure that the models are widely and appropriately used, the sponsoring agency must further develop a coordinated program of user support services, including: 1) training programs—with "hands-on" instruction, if possible; 2) one-on-one technical assistance, for problems that arise in the course of running the model and interpreting its results; and 3) model maintenance, to incorporate improvements and assure that users are informed of such modifications.

Agency expenditures in support of such a program need not be large. Services for frequently used models are often provided by the private sector on a paid consultant basis. Agencies may need only to provide rudimentary services, directing users to appropriate sources

of further assistance. However, the agency would need to ensure that the necessary support is available and of the highest quality.

For users with unique information and analytic needs, developing standard models to anticipate such needs may be inappropriate. **In these situations, strategies emphasizing general modeling capabilities, which stand in readiness to produce or adapt a model appropriate to each user's particular needs, may be more effective.** Such a strategy requires personnel capable of routinely coordinating model development, bringing scientific knowledge and modeling expertise to bear on unique situations. While the individual models require appropriate support (e.g., adequate testing and documentation), the process focuses on the needs of a single decisionmaker or decisionmaking group, rather than on those of many dispersed users.

Outstanding examples of both modeling approaches currently exist within the Federal Government. The Hydrologic Engineering Center (HEC) has extensively developed the capacity to maintain and support 12 Corps-built models. EPA, upon the completion of its Stormwater Management Model (SWMM), established the SWMM Users' Group to encourage the model's dissemination and use. More general modeling capabilities have been developed by USGS, which maintains a cooperative assistance program that provides services on a cost-sharing basis to over 600 State and local agencies.

Developing comprehensive strategies for building and disseminating water resource models is a pressing need for each of the Federal agencies involved in this field. While issue 1 addressed strategies for improving interagency coordination of water resource modeling activities, long-range intra-agency planning for the models and related support services within each agency's purview must supplement interagency coordination efforts.

An option available to Congress includes:

OPTION 3-A:

Congress could, through its oversight responsibilities, direct each of the major Federal water resource agencies to develop a coordinated strategy for the development, dissemination, and use of models.

OTA case studies indicate that coordinated planning is necessary for providing effective institutional support to encourage model development, dissemination, and use. While the approaches used in existing programs differ widely, successful efforts have two elements in common: 1) the models are of high quality, have been evaluated over a wide range of conditions, and are responsive to users' needs; and 2) the models are well documented and maintained, easily accessible, and are associated with adequate technical assistance. Oversight activities to ensure the development of a strategy incorporating each of these elements could help promote a more effective problem-solving capability within Federal agencies.

Two elements that are integral to the development of comprehensive modeling strategies—training and the availability of information about models—are discussed below as issues 4 and 5.

Issue 4: Providing Potential Users With Information About Existing Models

Many models currently developed by Federal agencies are intended for a single application—once they have been built, and are used to analyze a single problem, they are considered to have served their purpose, and are shelved. Since they are not designed for distribution, information on their existence is not typically made available outside the agency. Consequently, other agencies with potential uses for these models may be unaware that such models even exist. Often the models are not tested to determine their accuracy and applicability to other situations, nor are they sufficiently documented so that others may choose to use them. Models developed by outside contractors, but which are left undocumented or are documented inadequately, may not even be usable by other personnel within the same agency.

No entity within the Federal Government is specifically charged with providing information to potential users—Federal or non-Federal—about the governmentwide availability of water resource models. Three existing units provide such information as part of a more general mission; each, however, is limited in its ability to gather comprehensive information on existing Federal models, rapidly access that information for users, and match user needs to available models. The Water Resources Scientific Information Center (WRSIC), the National Technical Information Service (NTIS), and the General Services Administration's Federal Software Exchange Center (FSEC) provide information on models that have been documented and supplied to them by various Federal agencies. However, many Federal models are not entered into any of these systems, and many that have been entered have been inadequately documented.

A number of attempts have also been made at agency levels to provide relatively detailed information on models dealing with specific subject areas. Two of the larger systems dealing with water resource concerns are the Department of Agriculture's Land and Water Resources and Economic Modeling System, and the EPA Center for Water Quality Modeling.

In recent years, the concept of a model *clearinghouse* has gained many adherents in the scientific and managerial community. **Such clearinghouses would be designed to organize models for easy access by users with specific analytical needs.** To test the utility of the clearinghouse approach, EPA has sponsored the development of the International Clearinghouse for Ground Water Models (ICGWM) at the Holcomb Research Institute. Preliminary findings indicate that ICGWM has been very successful in improving the accessibility of

ground water models. Clearinghouses, however, remain a controversial approach. Some water resources professionals are skeptical of their cost effectiveness, and of any one organization's ability to provide expertise about large numbers of mathematical models.

Options available to Congress include:

OPTION 4-A:

Congress could direct the Federal water resource agencies to make information on agency models available to outside users and to establish mechanisms to distribute these models on request.

Several water resource agencies have already established catalogs of existing models, but on the whole, it is extremely difficult to obtain information about the existence and specifications of federally developed models. This information is generally unavailable to potential users in local, State, or other Federal agencies.

A second component of information transfer is the dissemination of the computer program for the model. Such programs are also generally difficult to obtain. Congress could direct agencies that do not presently distribute the results of federally funded modeling activities to do so at reasonable cost to the user.

OPTION 4-B:

Congress could expand the role of existing information transfer agencies to be more responsive to the modeling information needs of water managers, and encourage water resource agencies to use these existing mechanisms.

Either FSEC or WRSIC could be expanded to serve as a Federal Government-wide repository of water resource models and model information. Each of these groups currently provides limited information about water resource models—FSEC focuses directly on models, but has no water resource-related mission or expertise, while WRSIC is a comprehensive information source for water resource research, with no model-related mission or expertise. Neither provides the support services required for assisting potential model users.

Water resource agencies would have to be encouraged to assist the chosen information transfer agency in expanding its services.

OPTION 4-C:

Congress could establish a national clearinghouse system for the distribution of water resource models.

Though several model clearinghouses currently exist in the United States, many important water modeling areas are not covered by any existing organization. A centralized clearinghouse, or a series of clearinghouses, containing information on models of all aspects of water resources—quality and quantity of both ground and surface waters, as well as the social and economic implications of water use—could assist water managers to choose amongst the multitude of available tools.

"Seed money" would be required to start a national clearinghouse, but after several years of operation, equitably designed user fees could cover a substantial portion of clearinghouse operation costs. The clearinghouse should provide, at a minimum, information about available models. Additional services could include providing computer programs, or more extensive services such as training courses.

OPTION 4-D:

Congress could fund an interagency demonstration project to evaluate and compare existing models for a representative range of field conditions.

Though thousands of water resource models are currently available, few have been evaluated for conditions other than those under which they were developed. Information about the accuracy of models is difficult to obtain—and for many models is nonexistent. Poor validation of models is a significant constraint on model use.

For common types of analyses, such as projecting water quality changes from a proposed sewage treatment plant, Congress could direct the appropriate agencies to choose several models, evaluate them under a wide range of conditions, and compare their strengths and weaknesses for different purposes. The results of these evaluations would assist professionals in choosing tools appropriate to their needs, and give decisionmakers greater confidence in the results. If the demonstration program is successful, a more formal mechanism for interagency model evaluation might be established.

Issue 5: Federal Support for Model-Related Training

Federal funding currently provides much of the support for training personnel to develop, use, and interpret water resource models. However, **Federal, State, and private sector personnel reported that the inadequacy of current levels of model-related training is a major impediment to meeting the needs of local, State, and Federal agencies.** State water resource professionals considered increased federally sponsored training opportunities to be a top priority. In addition, officials of Federal agencies that sponsor training programs acknowledge that inadequate resources are presently provided for training nonagency personnel, and that current agency training opportunities fall far short of demand. If models are to be used effectively in water resource analysis, training in basic concepts of modeling and in proper interpretation of model results must be offered to decisionmakers at all levels of government. Finally, Federal support for the academic training of future water resource professionals has been threatened by recent cost-saving initiatives.

There are three major aspects to model-related training: 1) general educational opportunities in water resources research and analysis; 2) specific training in the use of individual water resource models; and

3) continuing education for manager/decisionmakers and users. Each involves a different kind of Federal training support.

Educating water resources professionals involves extensive academic training, and requires support for research and related overhead. Since 1965, the Office of Water Research and Technology (OWRT) of the Department of Interior has sponsored the University Water Research Program. The program provides seed money, through the State water resources research institutes, for training students in water-related studies and providing equipment for student and faculty research work. Over the past 16 years, the program has made a significant contribution to alleviating the shortage of qualified technical manpower for water resource management. Federal appropriations for the University Water Research Program have been reduced from approximately $11 million for fiscal year 1980 to approximately $6 million for fiscal year 1982. The fate of the University Water Research Program is still uncertain. OWRT has been scheduled for elimination, with its responsibilities to be transferred to other offices and programs, before the end of the current fiscal year.

Model users require specific training to enable them to use a particular model and apply it to actual problems. Such training is a critical component in transferring modeling technologies from the developer to the organizations charged with solving water resource problems. Many models go unused, or are underused, because such training is not widely available.

Managers and decisionmakers are often unprepared for the problems and complications associated with model use for water resource problems. Many have completed their formal education prior to the widespread use of computer modeling techniques, and do not understand the concepts underlying computer-based simulation and analysis. **Few Federal agencies have yet made a significant commitment to decisionmaker education and retraining to accommodate modeling techniques.** Federal efforts to provide continuing education in model use for management-level personnel are still in very early stages.

Options available to Congress include:

OPTION 5-A:

Congress could allocate resources to water resource agencies specifically for establishing inhouse and extramural training programs for their personnel, and for water managers in State and local agencies.

Two types of training programs are needed: 1) courses on the use of specific models for potential model users; and 2) continuing education for managers and decisionmakers to understand the strengths and weaknesses of model-based analyses.

Examples of training programs range from courses offered by HEC to the informal conferences of SWMM's Model User's Group. While

excellent examples of training programs exist for agencies to follow, the need for additional programs is great.

A variety of approaches could be used for developing adequate training programs. Agencies could arrange to fund training provided by universities with acknowledged expertise in water resource modeling, or develop inhouse training capabilities through agency personnel or outside contractors.

OPTION 5-B:

Congress could expand the current programs assisting university-level water resources education.

Training grants to universities, and research grants that provide the opportunity for students to obtain experience in analyzing water resource problems, are two mechanisms by which Congress can help provide an adequate supply of well-trained professionals.

Educating students in state-of-the-art analysis techniques, often available at universities throughout the country but not within Federal, State, and local agencies, brings these techniques to the agencies when these students graduate and are hired. Research and training programs offered through the National Science Foundation and OWRT are important mechanisms for meeting future agency-level analytical needs.

NOTE: Copies of the full report "Use of Models for Water Resources Management, Planning, and Policy" can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

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